The use of Landsat TM data in the study of total suspended solids associated with the Muda river plume

Md Noordin Abu Bakar, Faisal, Khiruddin Abdullah,
Mohd Zubir Mat Jafri, Abdul Hadi Abdul Rahman

School of Physics, Universiti Sains Malaysia, 11800 Penang, Malaysia

Abstract

Landsat TM data have been used to study total suspended solids (TSS) associated with the Muda river plume. An empirical approach of relating TM data with ground reference data for this parameter through regression analysis was done for estimating its concentrations over the coastal water. High concentration (>200 mg/l) of TSS was found (i) in the immediate vicinity out site the Muda river mouth and (ii) along the coast - to the north and south of the river mouth. The former result may be attributed to the direct effect of the river discharge whilst the latter being influenced by the wave activity along the shallow coastline. Result also shows that the concentrations of TSS within the plume area were satisfactorily correlated with the total monthly rainfall.

Key words: satellite image, river plume, TSS, coastal water

Introduction

Sediment distribution and accumulation in the coastal water environment usually originated from nearby rivers. The Muda River discharging into the adjacent coastal water creates a shallow (about 1.5 m depth) buoyant plume with low salinity values (Bakar et al., 2002). The plume dynamics is the result of its inertia, mixing with the ambient sea and the wind effects. The rate of the Muda river discharge was found to be dependent on the amount of rainfall, and this is particularly true for most river systems in the tropical region. The formation and spreading of river plume was first reported by Garvine (1974). Such plume often dominate the local physical and biological processes of the coastal water. Suspended sediments within the plume formation can act as natural tracers detectable by Landsat TM bands (Baban, 1993; Dinnel et al., 1990). This attribute, in combination with synoptic view and frequent coverage make such satellite data ideal for use in coastal region. In addition, the use of ordinary digital camera in studying the TSS around the Penang coastal water have been conducted recently (Lim et al., 2002).

Study Area

The Muda River is situated at the northwest part of peninsular Malaysia (Figure 1). The climate is dominated by the northeasterly monsoon (October to March) and southwesterly monsoon (April to September) with the former is relatively dryer than the latter. In addition, the transitional periods i.e. September/October and April/May are receiving the highest rainfall than any other months. Effectively, similar pattern can be seen in the Muda river discharge showing close relationship between rainfall and river discharge. During the wet months the discharge can reach up to 500 m^3/s. In contrast, the discharge can be reduced to about 30 m^3/s during the dry months. Generally, the water depth in the study area of the coastal region is shallow (up to 5 m).

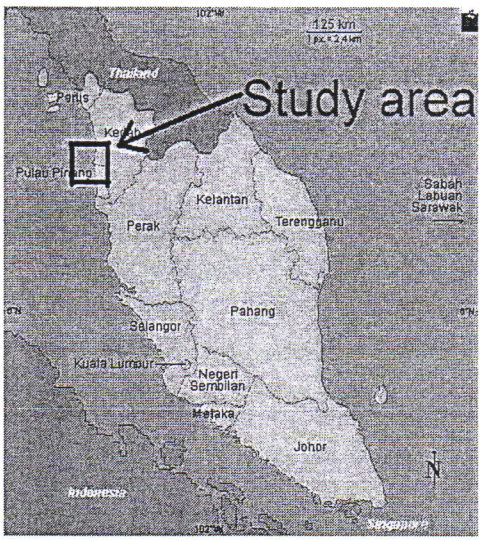


Figure 1: Study area.

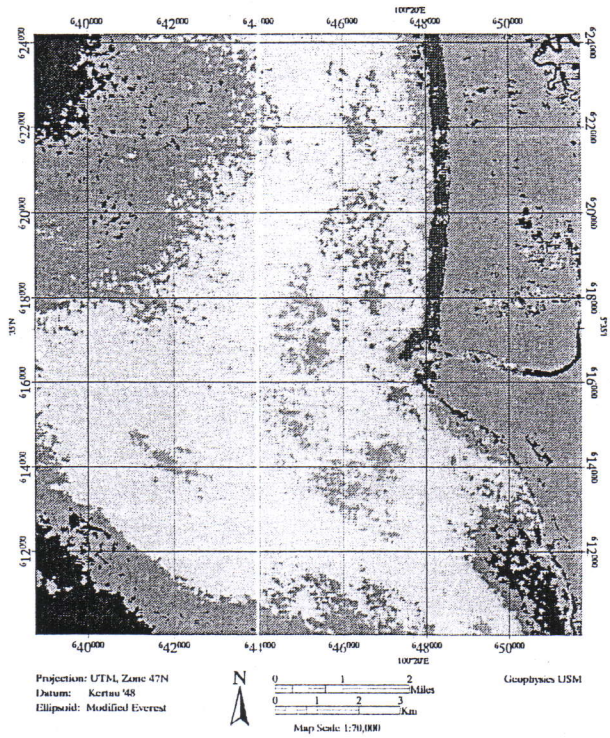
Methods

Five Landsat TM scenes acquired on 3 March 1998, 2 February 1999, 22 March 1999, 20 February 2000 and 30 July were used in this study. These scenes covered the whole Penang water, where sea truth data were available, including the Muda plume. The sub-scenes that contain the Muda plume region were extracted from the above scenes with size 1000x1500 pixels and then rectified to UTM geographical coordinates. The digital numbers of visible bands of the sub-scenes were extracted at the locations of the sampling stations. The average digital numbers for windows of 3x3 was found to produce the highest correlation.

In order to remove the difference in the atmospheric effects, detector responses and numerous other factors, the scenes were corrected according to the relative normalisation model by regressing the slave-scenes to a master scene using pseudoinvariant ground targets (Coppin and Bauer, 1994). The areas occupied by the TSS with concentrations higher than 200 mg/l were determined by calculating the number of pixels. Presumably, these areas represent the Muda plume region which was the primary aim of the present study.

Results

Figure 2a-2e show the generated maps of TSS for the 5 Landsat images following the method discussed above. In all but one case the TSS values are found to be above 200 mg/l. High values of TSS were observed in the immediate vicinity of the river mouth and along the coast to the north and south of the river mouth. These values can be seen to decrease as we move seaward/offshore where the water depth increase to more than 5 m.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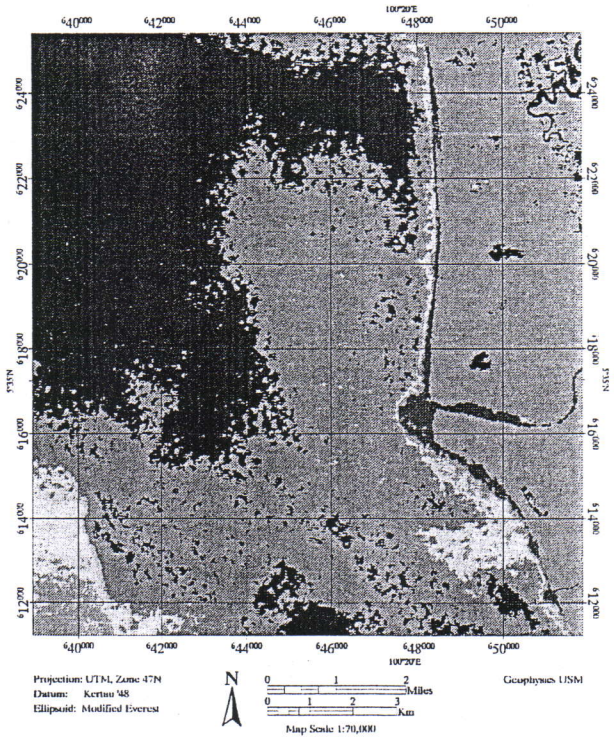
(a)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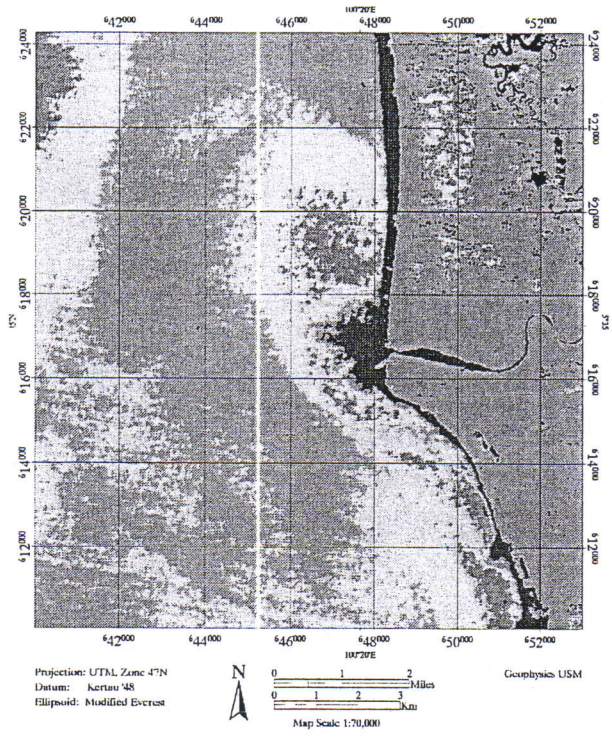
(b)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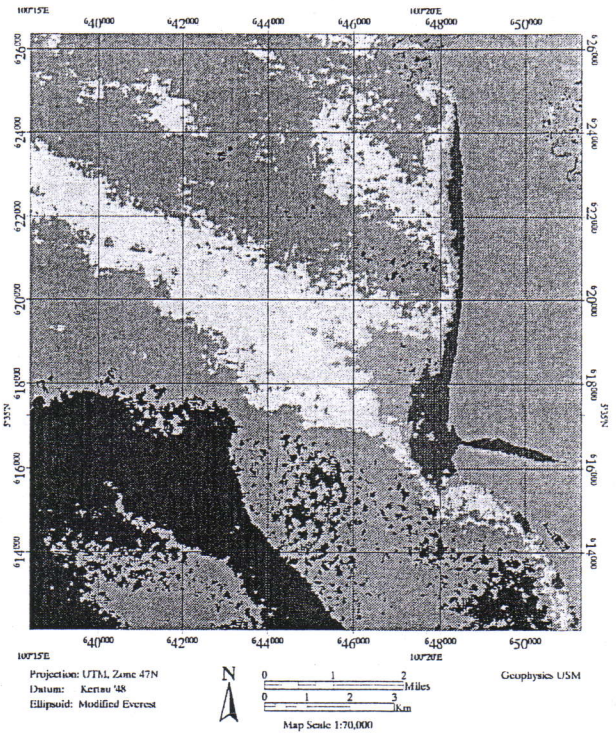
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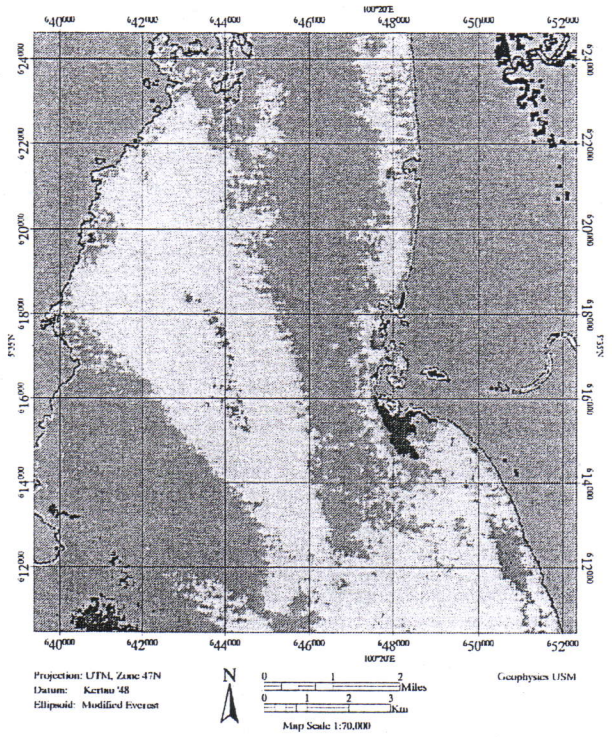

(e)

Figure 2. The generated maps of TSS for each date of TM data in Kuala Muda coatal water. (a) 2 March 1998, (b) 2 February 1999, (c) 22 March 1999, (d) 20 January 2000 and (e) 30 July 2000. The colours coded as: blue 0-50, green 55-100, yellow 100-150, orange 150-200, and red >200 mg/l.

As the result of the increase water depth we can expect the water body to becoming less turbulence (i.e. due to tidal stirring effects). Apparently, the rate of the settling of sediment in the water body is enhanced causing the observed gradual reduction of the value of TSS.

Figure 3 shows the horizontal profiles of the digital number of the image taken on 2 February 1999 for band 1 (blue), band 2 (green) and band 3 (red). The across shore profile (Figure 3a) represents the digital number taken in the east-west orientation of the river plume. The digital number for band 3 is seen to dramatically increase when approaching offshore boundary of the plume. Similar pattern for band 1 and band 2, however, were not clearly evidenced. The along shore horizontal profile (Figure 3b) taken in the north-south orientation of the river plume also shows increase in digital number within the plume region. The plot in Figure 4 shows extremely good relationship between the monthly rainfall and the calculated area of TSS or plume area. This indicates that the primary source of the TSS is the Muda River.

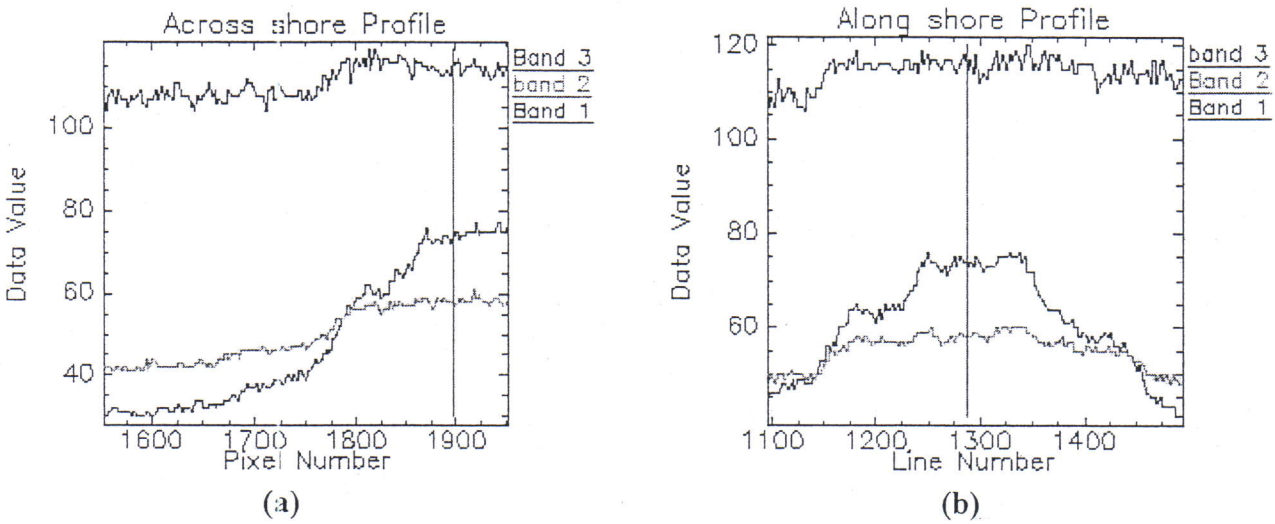

Figure 3. The horizontal profile of the digital number of the image taken on 2 February 1999 for band 1 (blue), band 2 (green) and band 3 (red).

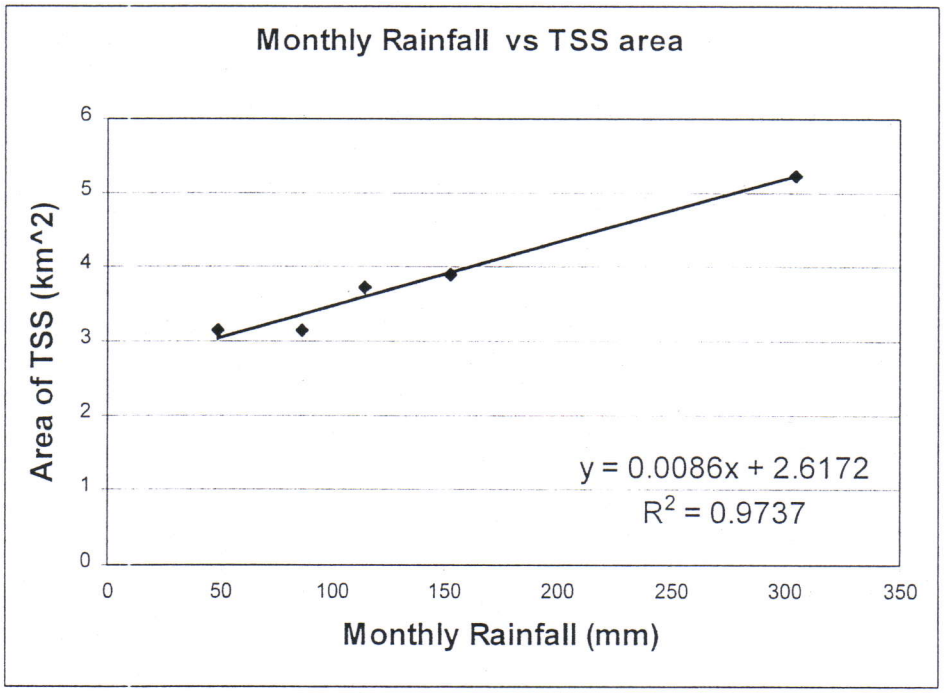

Figure 4. The relationship between the area of TSS concentration (>200 mg/l) and total monthly rainfall.

Conclusion

Landsat TM data have been successfully used in the study of TSS associated with the Muda river plume in the coastal water. The primary source of sediment in the shallow plume region was the Muda River discharge. Waves activity enhanced mixing and presumably causing the sediment into suspension in the water body. The concentrations of TSS within the plume area were satisfactorily correlated with the total monthly rainfall.

Acknowledgments

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